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Development of microstrip antenna array for monopulse application

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Abstract . The radiation and impedance properties of a microstrip patch antenna array have been investigated experimentally The antenna structure consist of four cornerfed square patch array which are arranged properly to fit four quadrants of a circle This type of configuration is choosen to use it with monopulse comparator The antenna is matched with its feed line by impedance transformer Experimentally observed results are comparable to that obtained theoretically

Keywords : Microstrip antenna, corner fed square patch array radiation and impedance properties

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1. Introduction

The feed network of microstrip array exhibits losses which lead to a limit on the expected gain and consequently a limited number of elements. Taking the elementary radiation pattern into account a simple structure using square shaped microstrip patch can be considered for a linear series array with low sidelobe level, high gain and low cross polarisation.

It is very easy to feed each element of a corner fed square patch and the array can be fed along a straight microstrip line as shown in Figure 1. Also a tapered distribution is readily obtained using quarter wave length transformer along the line They provide a high input impedance well suited for series array.

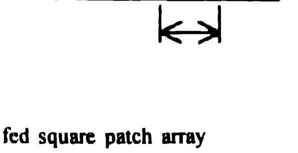

Figure 1. Corner fed square patch array

A complete microstrip array can be designed with monopulse comparator [1] at the centre of the aperture [2,3]. Each array is corporately fed with monopulse comparator on a separate layer [4]. But this configuration has major disadvantage that spurious radiation from comparator circuit may degrade antenna performance. An alternative configuration may be proposed which combines four crossfed array within a circular geometry with the provision of providing the monopulse comparator circuit on a separate PCB at the back of the antenna. In this article a technique for development of 18 element crossfed patch antenna array is presented.

2. Theory

The geometry of the patch is shown in Figure 2. When a patch is excited at one corner, cavity model [5,6] shows that

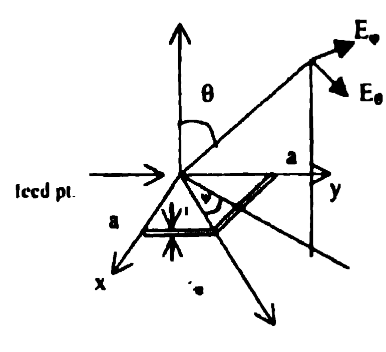

Figure 2. Geometry of corner fed square patch

main part of the internal field is sum of two degenerate mode with equal amplitude modes (1,0), (0,1). If the higher order modes are ignored, *Ex*, *Ey* fields along the edges exhibits variation shown in Figure 3. The far field is linearly polarised in E plane or H plane. The discontinuities introduced near the corner of each element are symmetrical and identical for all of them. Thus co-polar and cross polar components remain symmetrical around the broadside direction.

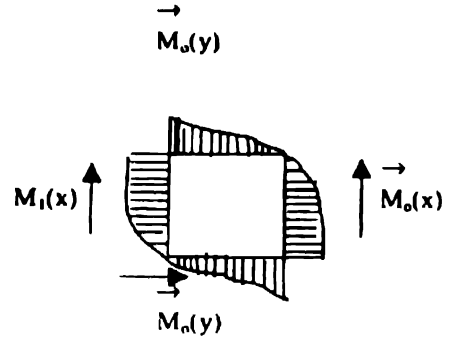

Figure 3. Magnetic currents of corner fed patch

For uniform illumination, the spacing along feed line equals one guided wavelength. In the H-Plane nulls of each sub array factor have different locations because the sub array have a different number of elements. Then all subarray components are added in phase in the broadside direction while a compensation occurs from the oscillatory function outside $\theta = 0$.

The input impedance (refer to Figure 4) are different for the half main line section $R1$ and the upper and lower group of subarrays $R2$. The impedance matching needs one or two

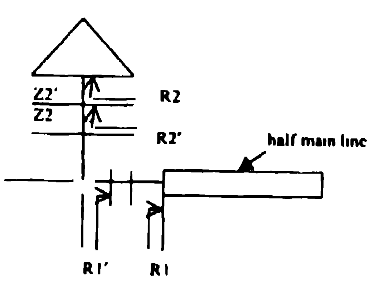

Figure 4. Input matching transformers of the cross-fed array

quarter wave transformer to get suitable characteristic impedance $Z2'$, $Z2$, $Z1'$, $Z1$. The uniform illumination condition yields a relation involving transformer impedance ratios, being equal on each side.

$r = Z2'/Z2 = Z1'/Z1 = (1/N)(2Ra/Ro)$ where Ra = resistance of corner fed antenna.

Ro = desired input impedance, N = number of elements on main line.

But only the impedance matching condition does not provide a uniform illumination, because if different quarter wave transformer are used on each arm of the structure, voltage on each element of upper and lower subarray differs from voltages of central line.

3. Design

The basic radiating elements are corner fed square patches inclined 45° along the feeding line. In order to get broadside beam one wavelength spacing is necessary. Half wavelength spacing is also possible with alternate elements to keep the equiphase condition. Cross polarisation level can be reduced by using alternate elements on the feeding line. Reduction of side lobe level can be done using simple tapering along linear series array.

The overall array is contacted from parallel subarrays. The number of elements is reduced from Ni to N_{i-2} considering i-th and $(i + 1)$th subarray respectively, where N is the number along the disgonal. Total number of elements for the upper and lower group of subarray is equal to $N(N-2)/4$ and for the whole array $Nt = N^2/2$. Considering the size of the antenna N can be calculated and corresponding number of subarray is found out. Computed radiation pattern shows the gain of the array is 21.6 dB. According to the pattern multiplication principle actual gain of the antenna array will be determined by adding gain of the single rectangular patch which is of the order of 6 dB. So total gain for a single quadrant increases above 25 dB. By considering 4 such quadrants overall gain of the antenna is increased by $\log_{10}(4)$ dB.

The entire design is done for Ku band (fo = 18 GHz, BW = 1 GHz). A 18 element crossfed array has been realised for a frequency near 18 GHz. For this a six element array along the main diagonal and accordingly four subarrays has been constructed for a single quadrant and four such quadrants are combined together on a single PCB (RT-duroid, $\varepsilon_r = 2.2$, thickness = 0.787 mm) within a circular area of radius 85 mm. The requirement is to get a sidelobe level lower than –25 dB and gain 25 dB. For input impedance matching, two quarter wave transformer are used, one of which is a two stage transformer fabricated and perpendicular to the central line while the other one is along the central line. The purpose in both the cases is to impedance match the feeding lines to 50 ohm (SMA) connector impedances. The transformer impedances are suitable for easy realisation with microstrip line.

(i) Length of single square patch = 5.6 mm,

(ii) Inter element spacing along diagonal = 11.41 mm,

(iii) Sub array spacing = 11.41 mm,

(iv) Width of the central line = 0.17 mm.

4. Results

The experimental plot of E plane and H plane radiation pattern shows side lobe level better than –20 dB. Input impedance matching is also very closed to desired value (1.001). Also for all four arrays impedance matching closely resembles within 0.5% to earth other at the centre frequency. The beamwidth obtained from radiation pattern are 20°, 24° in *E* plane and *H* plane respectively. The gain is calculated to be 17.6 dBd.

5. Conclusion

In this paper, a novel technique for development of four similar crossfed array into 4 quadrants of a circular plate with 4 SMA output is presented. So this type of antenna is suitable for modern system where low cost, light weight and low profile antennas are required. Major application lies in monopulse circuits.

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